JPL PUBLICATION 78-15, VOLUME XIII

Characterization of Solar Cells for Space Applications

Volume XIII. Electrical Characteristics of Hughes LPE Gallium Arsenide Solar Cells as a Function of Intensity and Temperature

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ACKNOWLEDGEMENT

The authors gratefully acknowledge the invaluable assistance of James Hix and Diane Engler for computer programming and meticulous attention to detail in producing the tables and plots. The absorptance measurements were performed by Jerry Brown of the TRW Thermophysics Laboratory.

ABSTRACT

Electrical characteristics of Hughes liquid phase epitaxy, P/N gallium aluminum arsenide solar cells are presented in graphical and tabular format as a function of solar illumination intensity and temperature.

CONTENTS

Figures

Tables

SECTION I

INTRODUCTION

A series of reports is being generated to present parametric characterization data on both state-of-the-art and developmental solar cells of interest to the photovoltaic community. These data consist of electrical characteristics of the candidate solar cell under a wide range of temperature and illumination intensity combinations of the type encountered in typical space applications. This series (JPL Publication 78-15) consists of a number of reports, each report being devoted to a particular type of solar cell and identified by a volume number. Previously published reports with their associated solar cell descriptions are listed in the bibliography. Each report consists primarily of working graphs and tables and does not address itself to interpretive conclusions. The formatting of this series of reports is relatively invariant to facilitate comparisons between the characteristics of any of the cell types considered in the series. This report contains a set of parametric data on Hughes LPE gallium arsenide solar cells.

SECTION II

CELL DESCRIPTION

The cells reported here were manufactured by Hughes Research Lab. The cells are made by growing a GaAs buffer layer by liquid phase epitaxy (LPE) on a conventional n+ GaAs substrate. The first portion of the buffer layer is n-type (doped with 10^{17} cm^{-3} Sn), and the second portion is p-type (doped with 10^{18} cm^{-3} Be), resulting in a P/N junction. A window of p-type $Al_xGa_{1-x}As$ (with x typically .95) is grown over the buffer layer using Be doping to a concentration of 10^{18} cm^{-3}. Total buffer layer thickness is 10 microns, junction depth is $\leq$0.5 microns and window layer thickness is $\leq$0.5 microns. Total cell thickness is approximately 300 microns. The front contact geometry is a pattern of 24 parallel grid fingers, each terminating in a 0.079 by 2 cm busbar located at a cell edge. Front contact material is sputtered Au-Zn followed by a Ag evaporation. The rear contact is a picture frame pattern of evaporated Au-Ge-Ni followed by a Ag evaporation. The cells used in this test were covered with 7940 fused silica coverslides, 300 microns thick with an antireflection coating of magnesium fluoride and a 350 micron cut on filter. The coverslides were mounted to the cells using Dow Corning DC 93-500 adhesive.

SECTION III

TEST PROGRAM

The solar cells were mounted on a copper test plate using RTG 560. The test plate was in turn mounted to a heat sink with provisions for both heating

and cooling so that the cells could be maintained at the desired temperature independent of the solar intensity. All testing was carried out in vacuum at a pressure of less than 1×10^{-6} torr.

The illumination source used was a Spectrolab Model X-25 Mark II Spectrosun filtered solar simulator. This simulator uses an optical integrator lens in the optical system that uniformly distributes a relatively collimated light beam at specific distances from a 2.5-kW short-arc xenon lamp. A system of filters modifies this spectral distribution so that it approximates that of space sunlight. The light beam provides a pattern having a uniformity of ±1% over an area of 225 cm^2 at the test plane. Illumination intensity is varied by position of the simulator in combination with transmission filters. The solar simulator beam is introduced into the vacuum chamber through a window of 7940 fused silica. The solar intensity and spectral integrity of the solar simulator are constantly monitored and maintained using space-calibrated standard cells obtained with the NASA/JPL solar cell balloon flight standardization program. Photographs of the solar cell, the assembled plate, and the experimental characterization test facility are shown in Figures A-1 through A-4 in the Appendix.

The temperature range covered in these measurements was -20 to 200°C, while the solar intensity range covered was 50 to 500 mW/cm^2. The data were taken at each environment point in the matrix in the form of an I-V curve. The appropriate parameters were then read from the I-V curves and punched on cards for the computer analysis and curve plotting functions. The cell temperature was monitored by a thermocouple attached to the busbar of a cell under test. Prior, intermediate, and post-test ambient measurements were performed daily to insure that the accuracy and stability of the test equipment and the test specimens themselves were maintained within ±2% during the course of the testing program.

Three cells from the same lot of cells, two with cover slides and one without, were sent to TRW for absorptance measurements. These measurements were made using a Gier Dunkle integrating sphere spectrometer. The reflectance is measured over the wavelength range 0.28 to 2.5 micrometers. Absorptance is calculated by weighting the reflectance with the AMO spectrum and subtracting from one.

These cells are currently being irradiated with 1-MeV electrons. The radiation data will be published in a future report.

SECTION IV

DISCUSSION OF RESULTS

A computer program computes statistical averages and standard deviations with respect to the measured cells for each intensity-temperature measurement condition. It then produces summary tables, as shown in Tables 1 to 7, that display averages and standard deviations of the cell characteristics in a two-dimensional array format, one dimension representing cell temperature and the second dimension representing incoming light intensity (AMO spectrum). The program then produces plots of the various electrical parameters of interest, with either incident intensity or cell temperature as the independent variable, as shown in Figures 1 to 14. Least square fits to the

data points are then made automatically to the measured data points using a second-degree polynominal for most parameters. The curve factors, AMO efficiencies, V_{oc} and V_{mp} data points, are not fit but interconnected from point to point. In addition, the program calculates the temperature coefficients of the pertinent cell electrical parameters of interest, using the aforementioned curve fits, and plots these as a function of temperature, with intensity as a parameter, as shown in Figures 15 through 18.

The figures are intended to be working artifacts; that is, they are formatted in such a way that they can supply information of a general nature or may be used to generate predictions, comparisons, computer input data, etc. To facilitate comparisons and inputting, all units are standardized as follows:

(1) All currents are in units of mA/cm^2.

(2) All voltages are in units of mV.

(3) All power outputs are in units of mW/cm^2.

(4) All curve factors are in dimensionless units.

(5) All efficiencies are in percentages and are based on cell area.

(6) All temperatures are in ^oC.

(7) All incoming intensities are in units of mW/cm^2 and are representative of an AMO spectrum.

(8) All geometric dimensions are in units of cm or μm (whichever is most convenient conceptually.

The tables included in this report contain complete numerical information with respect to the average values of the following solar cell electrical parameters: I_{sc}, V_{oc}, I_{mp}, V_{mp}, P_{max}, CF, and efficiency at each intensity-temperature combination. For each such parameter at each such intensity-temperature combination the standard deviation is presented to provide estimates of statistical validity. All efficiency, current, and power output data is on the basis of unit area derived by dividing measured output by total cell area.

The average absorptance of the two covered cells was found to be 0.779 and the average absorptance of the bare cell was 0.768.

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Volume II. Electrical Characteristics of Solarex 50 Micron Solar Cells as a Function of Intensity and Temperature, August 1978.

Volume III. Electrical Characteristics of OCLI Hybrid MLAR Solar Cells as a Function of Intensity and Temperature, September 1978.

Volume IV. Electrical Characteristics of Spectrolab BSF 200-Micron Helios Cells as a Function of Intensity and Temperature, November 1978.

Volume V. Electrical Characteristics of OCLI 225-Micron MLAR Wraparound Cells as a Function of Intensity, Temperature, and Irradiation, April 1979.

Volume VI. Electrical Characteristics of Spectrolab BSF, BSR, Textured 10 ohm-cm, 50 Micron Advanced OAST Solar Cells as a Function of Intensity, Temperature, and Irradiation, June 1979.

Volume VII. Electrical Characteristics of Spectrolab HEWAC BSF, Textured, 10 ohm-cm, 225 Micron Solar Cells as a Function of Intensity and Temperature, June 1979.

Volume VIII. Electrical Characteristics of Spectrolab BSF, BSR, Textured, 10 ohm-cm, 290 Micron Solar Cells (K7) as a Function of Intensity, Temperature, and Irradiation, July 1979.

Volume IX. Electrical Characteristics of Spectrolab BSF, Textured, 10 ohm-cm, 200 Micron Solar Cells as a Function of Intensity, Temperature, and Irradiation, September 1979.

Volume X. Electrical Characteristics of Spectrolab BSF, Textured, 10 ohm-cm, 300 Micron Solar Cells as a Function of Intensity and Temperature, October 1979.

Volume XI. Electrical Characteristics of Spectrolab 2 ohm-cm Wraparound Solar Cells as a Function of Intensity and Temperature, January 1980.

Volume XII. Electrical Characteristics of Solarex BSF, 2 ohm-cm, 50-Micron Solar Cells (1978 Pilot Line) as a Function of Intensity, Temperature, and Irradiation, March 1980.

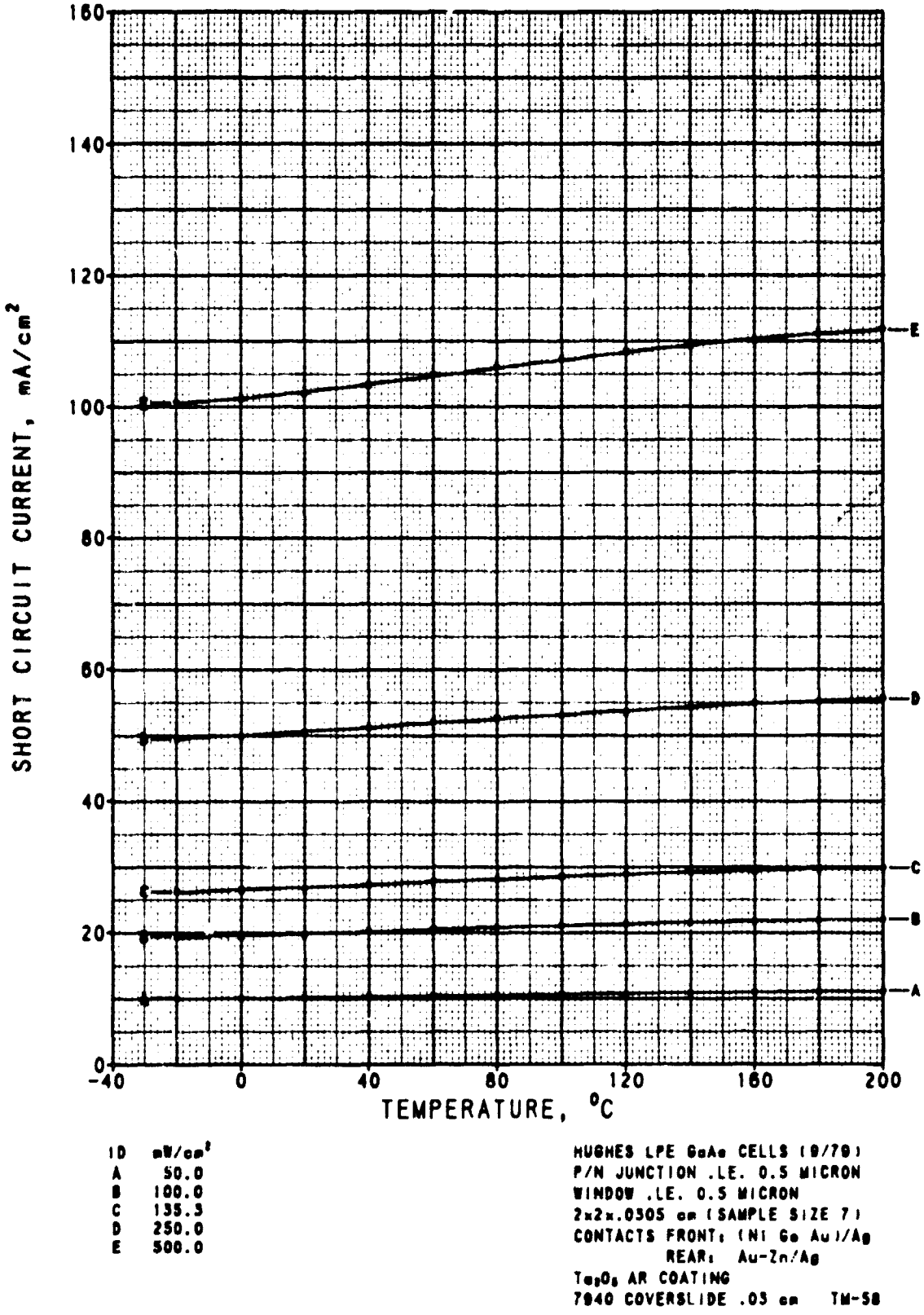


Figure 1. Average I_{sc}/cm^2 as a Function of Temperature

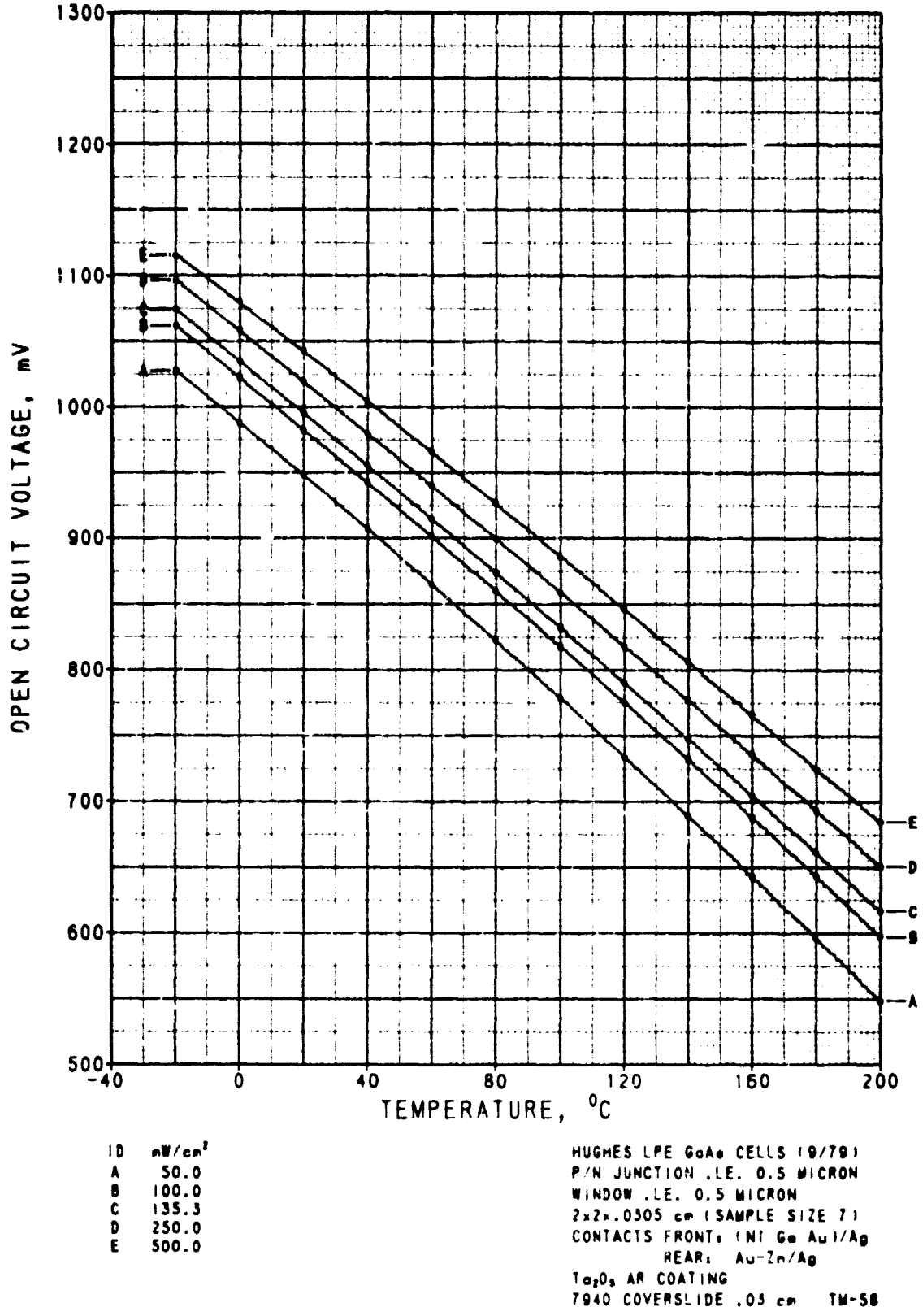


Figure 2. Average V_{oc} as a Function of Temperature

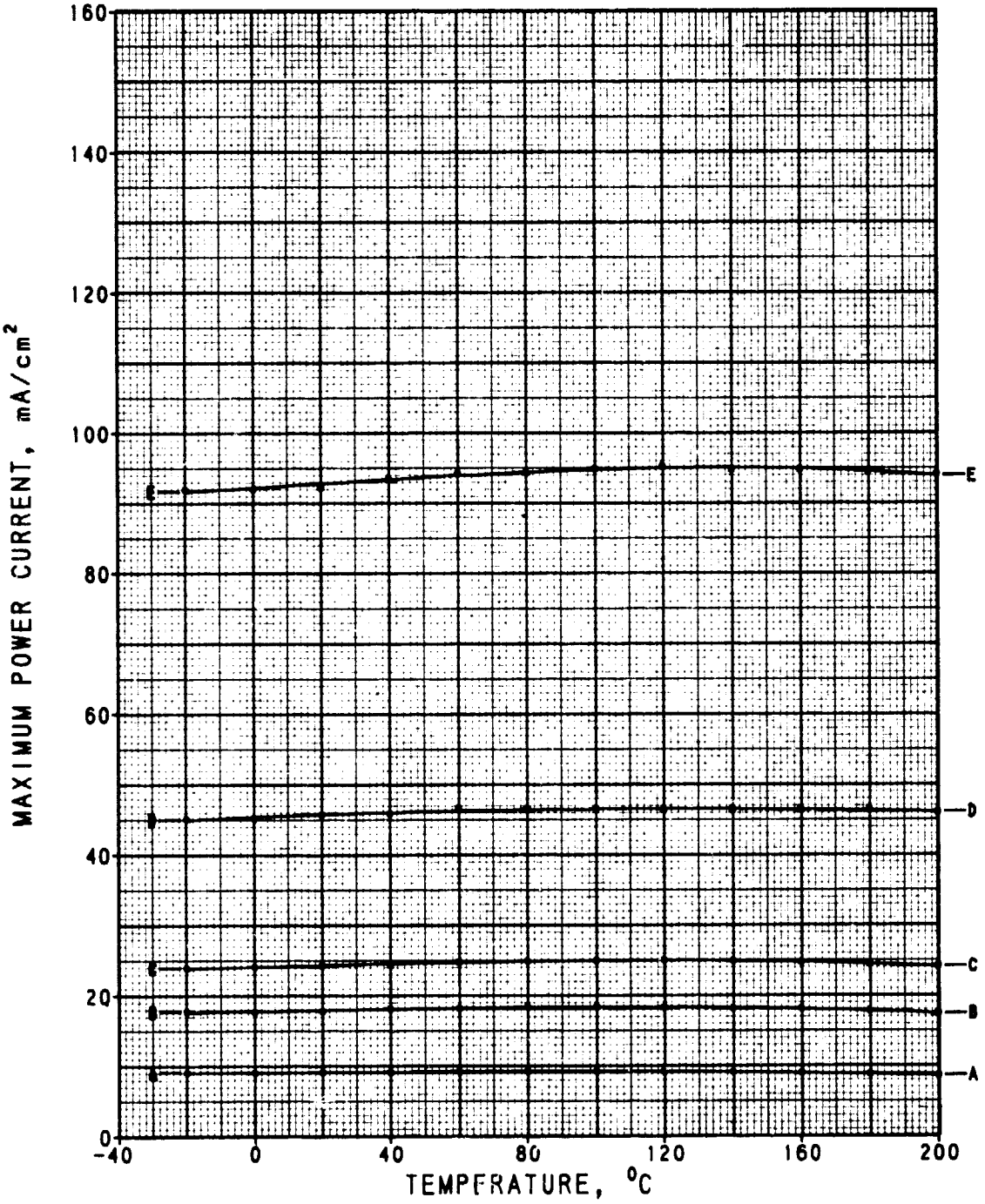


Figure 3. Average I_{mp}/cm^2 as a Function of Temperature

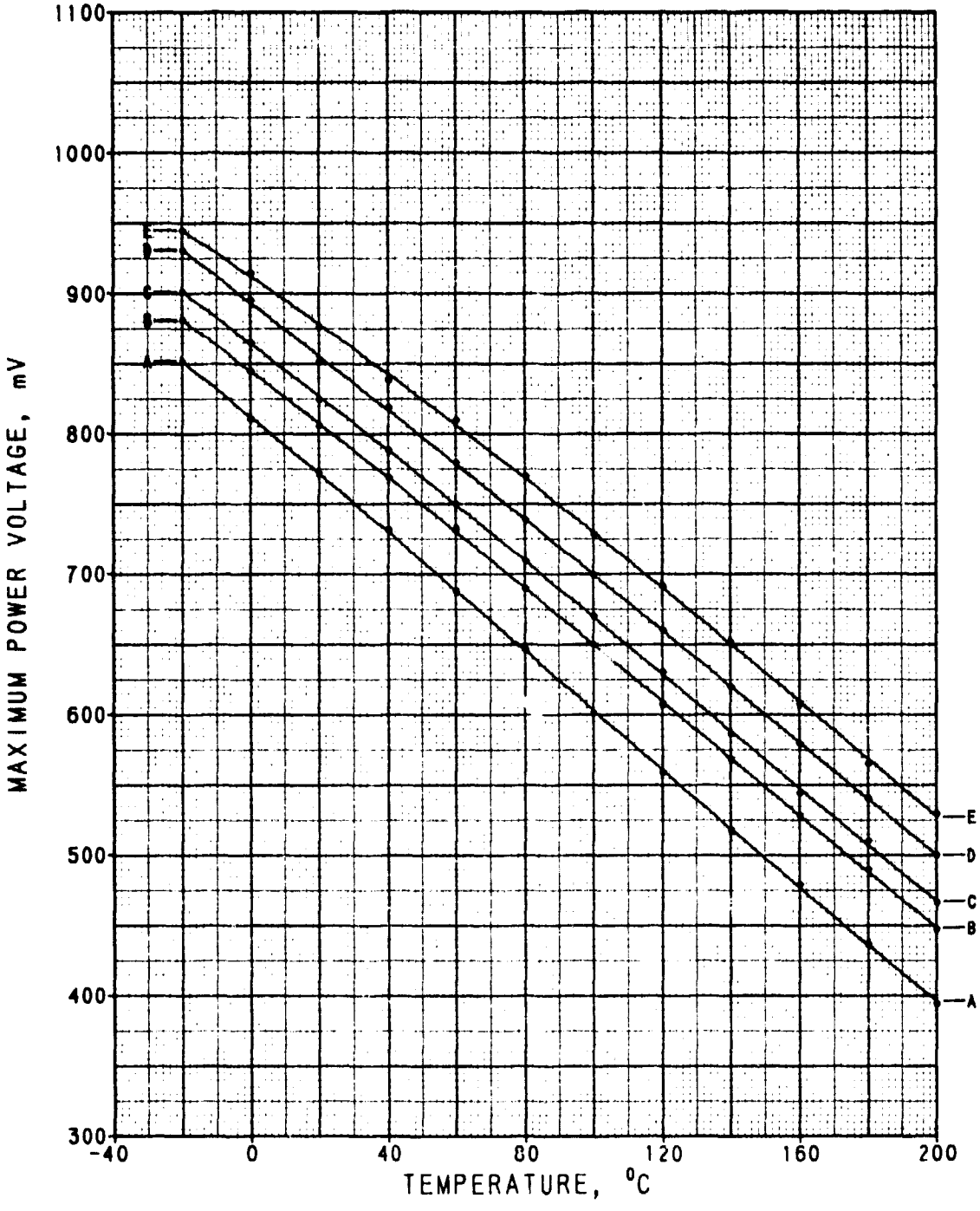


Figure 4. Average V_{mp} as a Function of Temperature

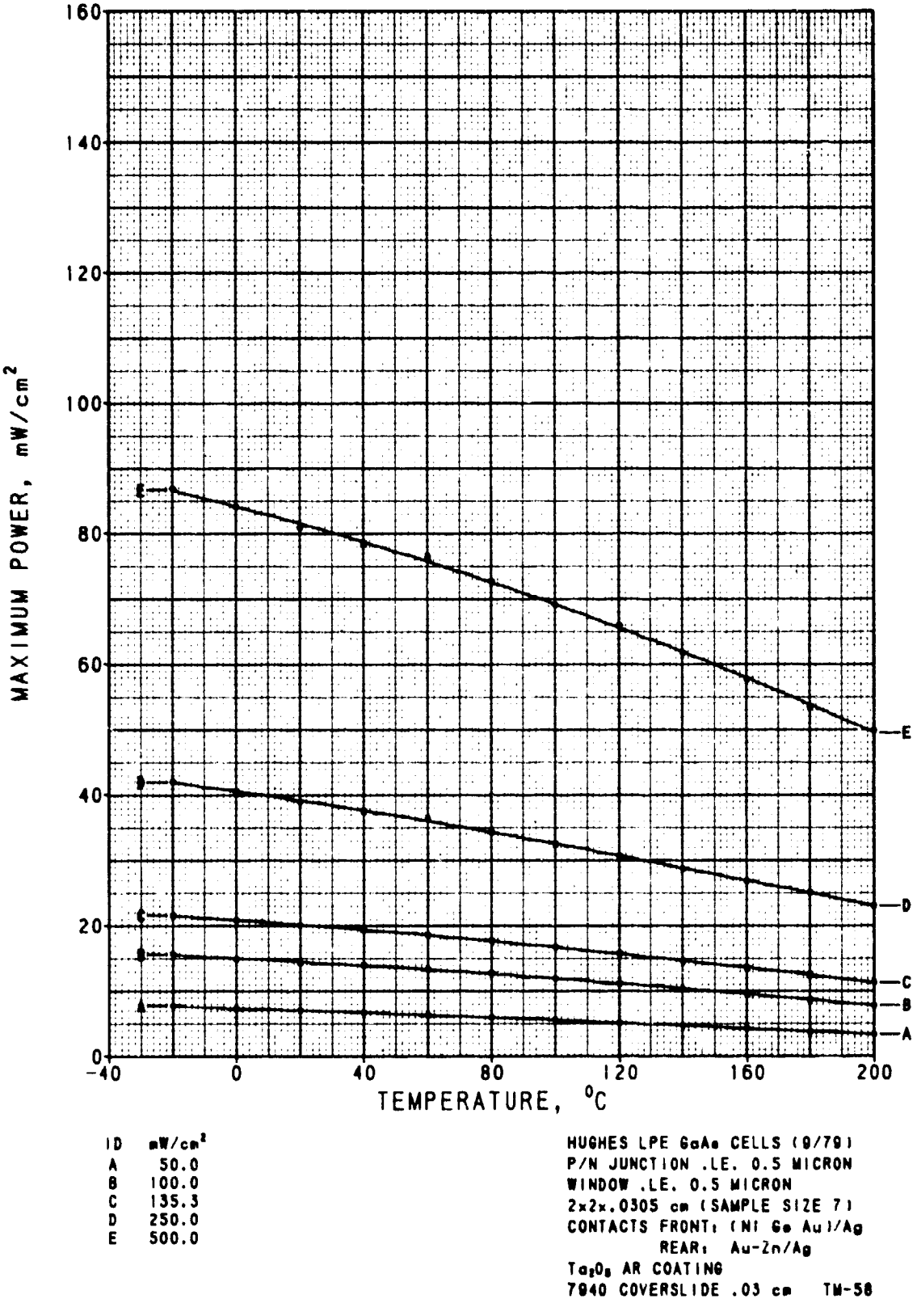


Figure 5. Average P_{max}/cm^2 as a Function of Temperature

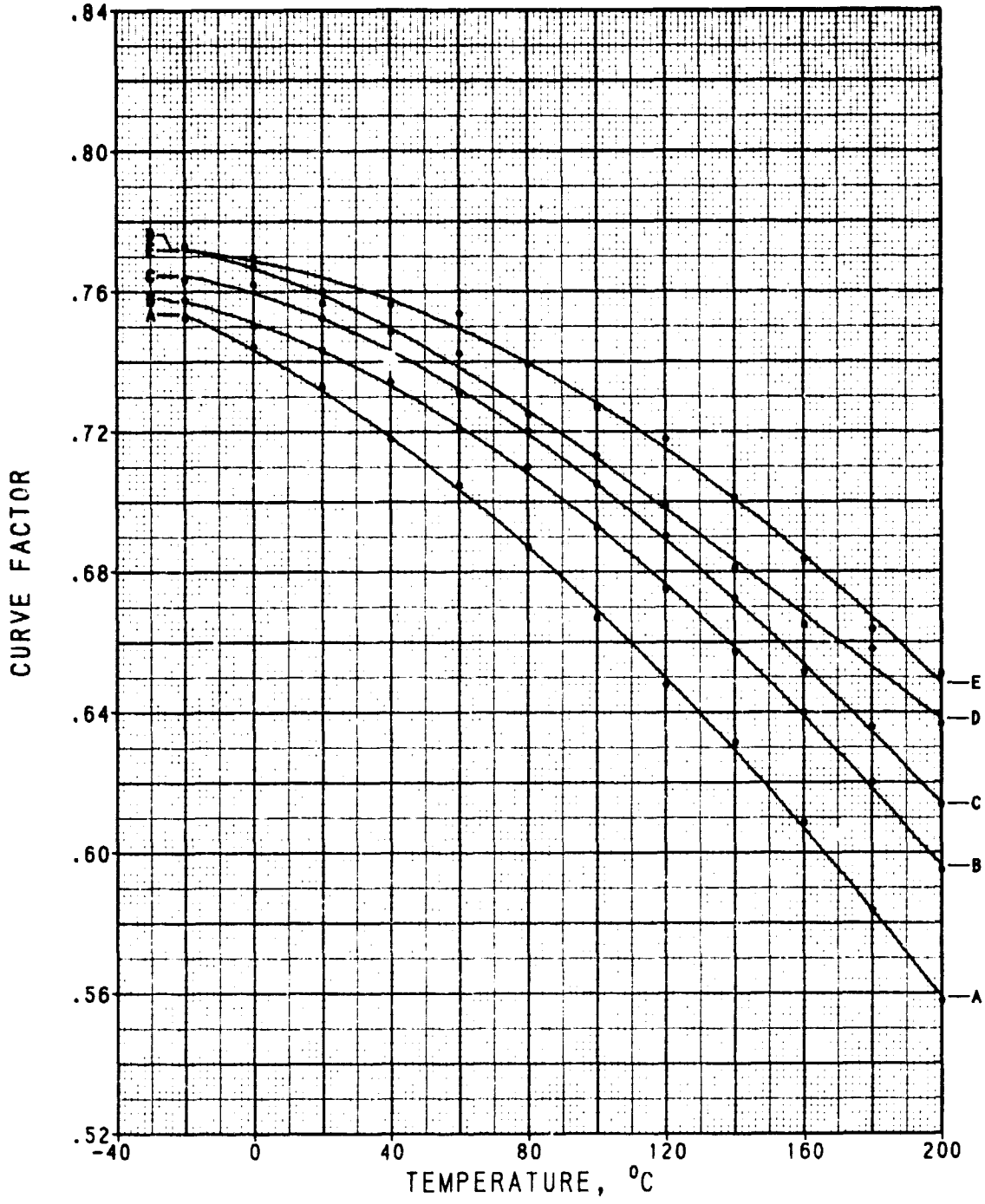


Figure 6. Average Curve Factor as a Function of Temperature

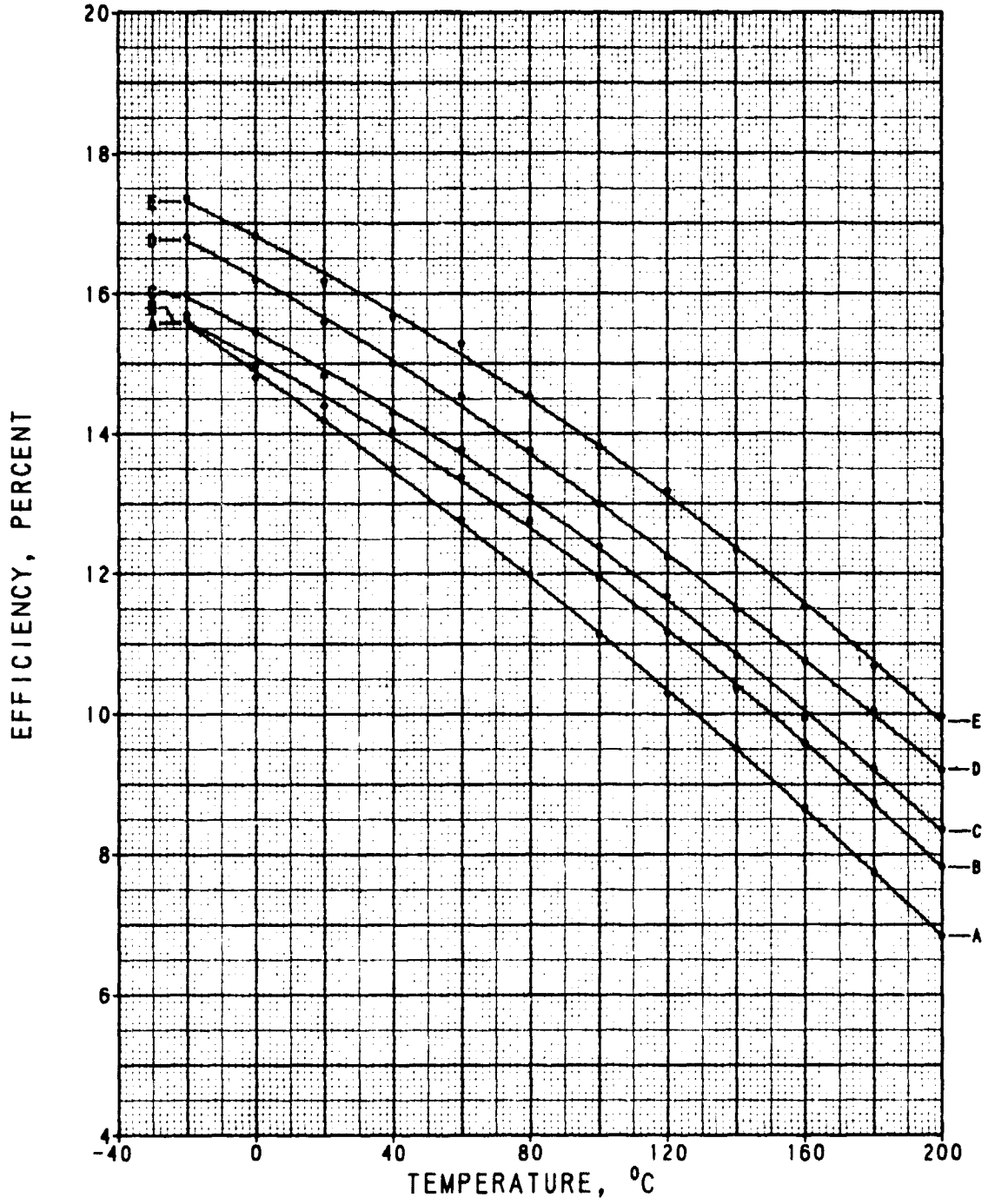


Figure 7. Average AMO Efficiency as a Function of Temperature

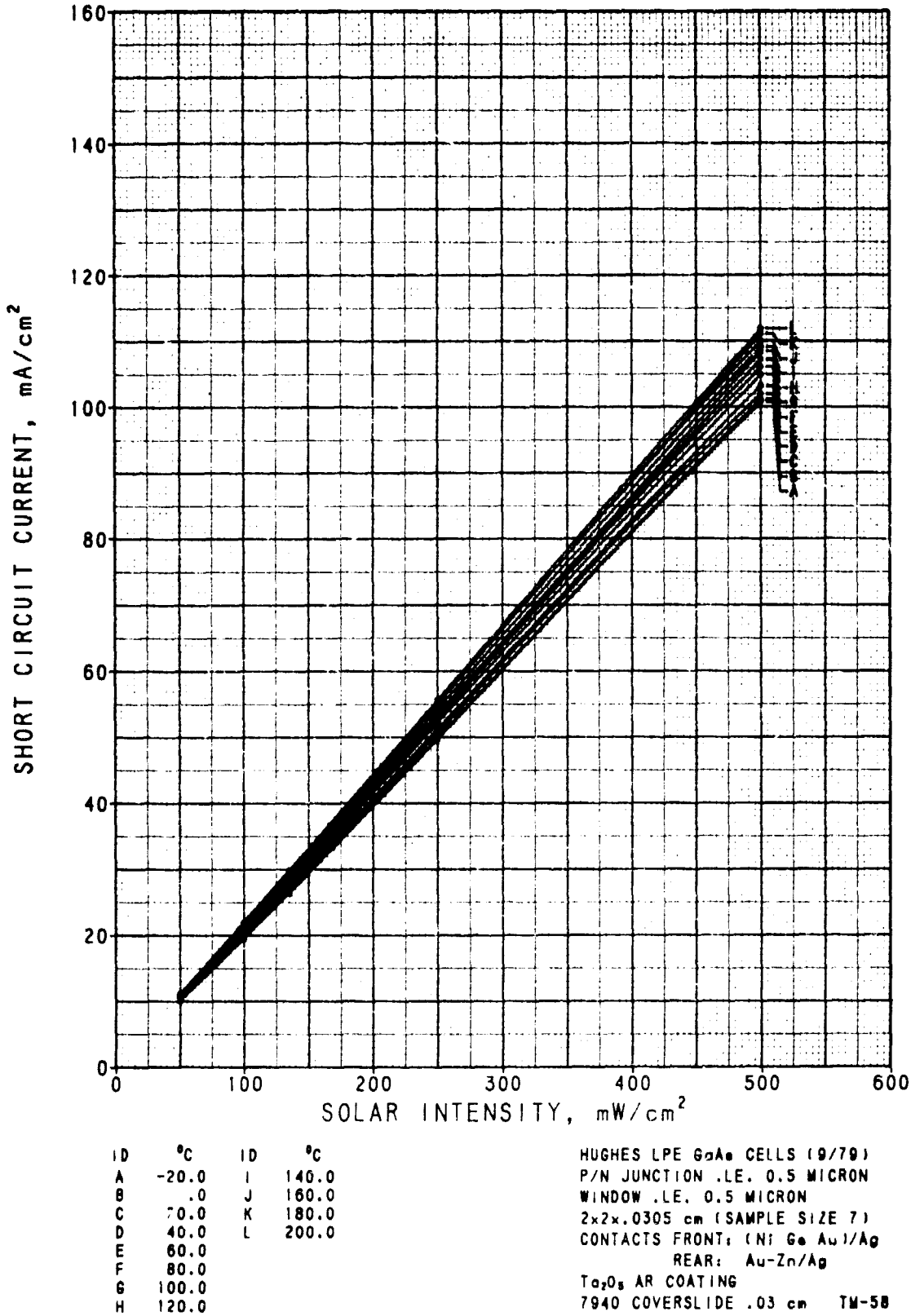
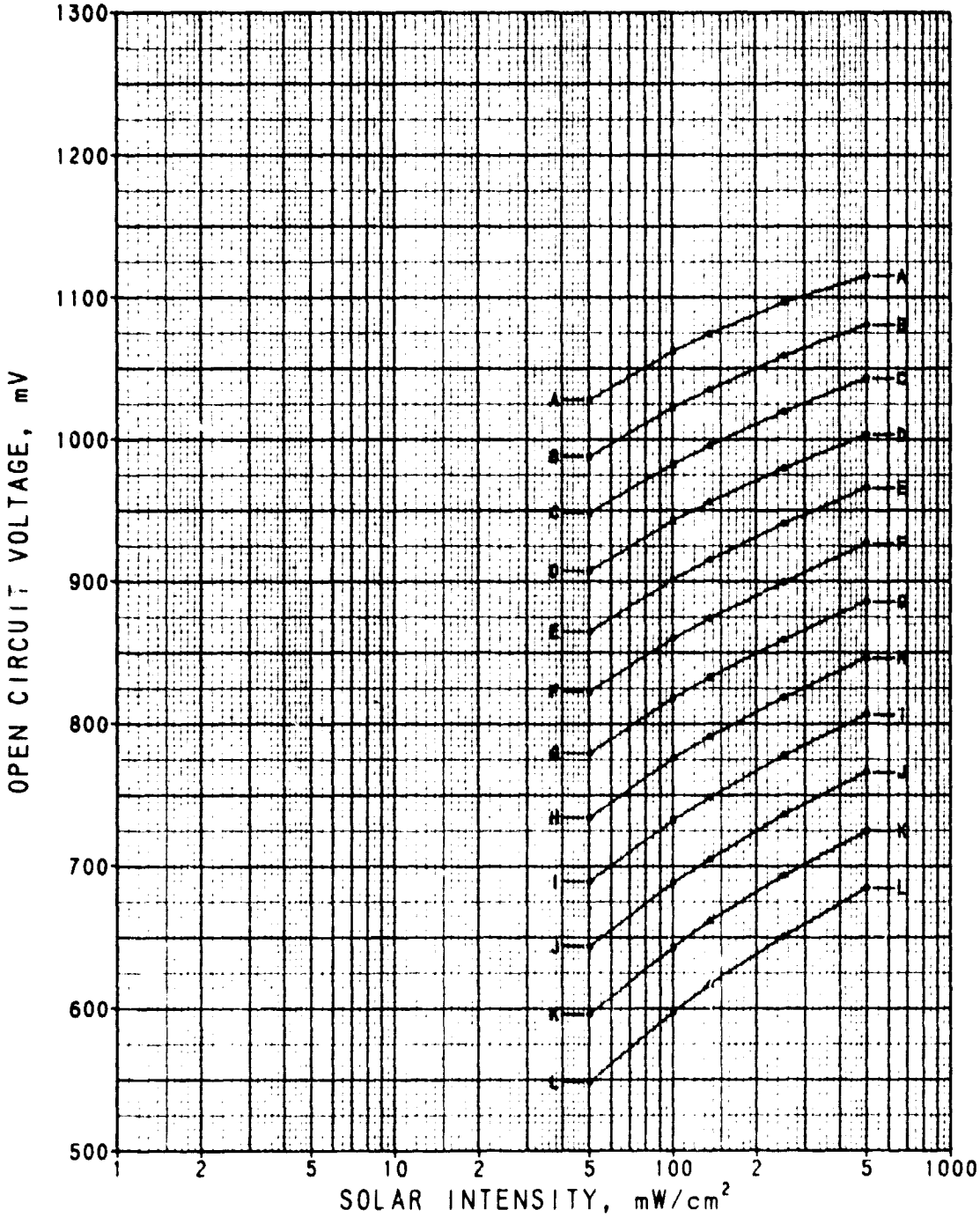


Figure 8. Average I_{sc}/cm^2 as a Function of Intensity



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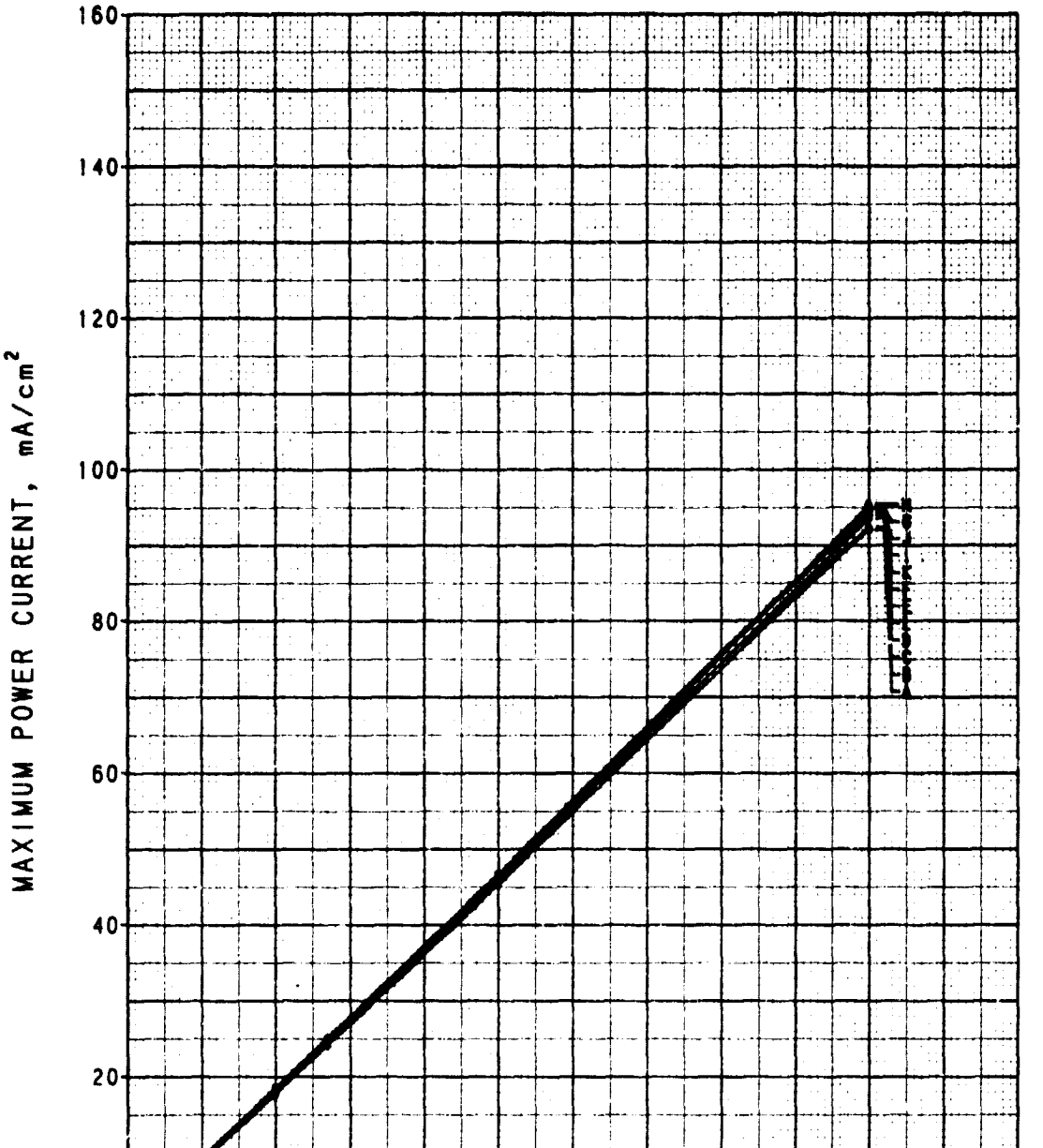
A	-20.0	I	140.0
B	.0	J	160.0
C	20.0	K	180.0
D	40.0	L	200.0
E	60.0		
F	80.0		
G	100.0		
H	120.0		

HUGHES LPE GaAs CELLS (9/79)
P/N JUNCTION .LE. 0.5 MICRON
WINDOW .LE. 0.5 MICRON
2x2x.0305 cm (SAMPLE SIZE 7)
CONTACTS FRONT: (NI Ge Au)/Ag
REAR: Au-Zn/Ag
Ta_2O_5 AR COATING
7940 COVERSLIDE .03 cm TM-58

Figure 9. Average V_{oc} as a Function of Intensity



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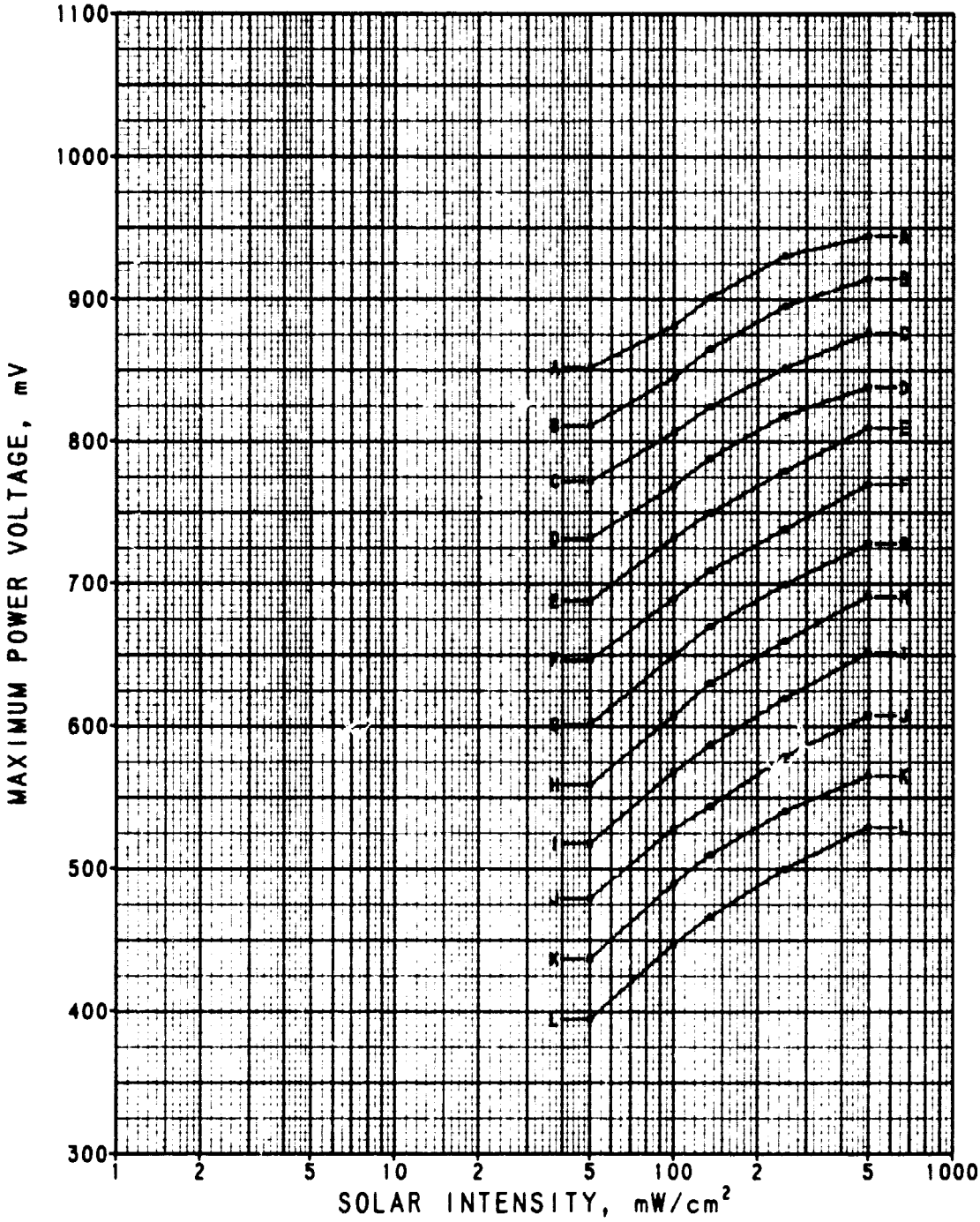
B	.0	J	160.0
C	20.0	K	180.0
D	40.0	L	200.0
E	60.0		
F	80.0		
G	100.0		
H	120.0		

HUGHES LPE GaAs CELLS (9/79)
P/N JUNCTION .LE. 0.5 MICRON
WINDOW .LE. 0.5 MICRON
2x2x.0305 cm (SAMPLE SIZE 7)
CONTACTS FRONT: (Ni Ge Au)/Ag
REAR: Au-Zn/Ag
Ta_2O_5 AR COATING
7940 COVERSLIDE .03 cm TM-58

Figure 10. Average I_{mp}/cm^2 as a Function of Intensity



ID	°C	ID	°C
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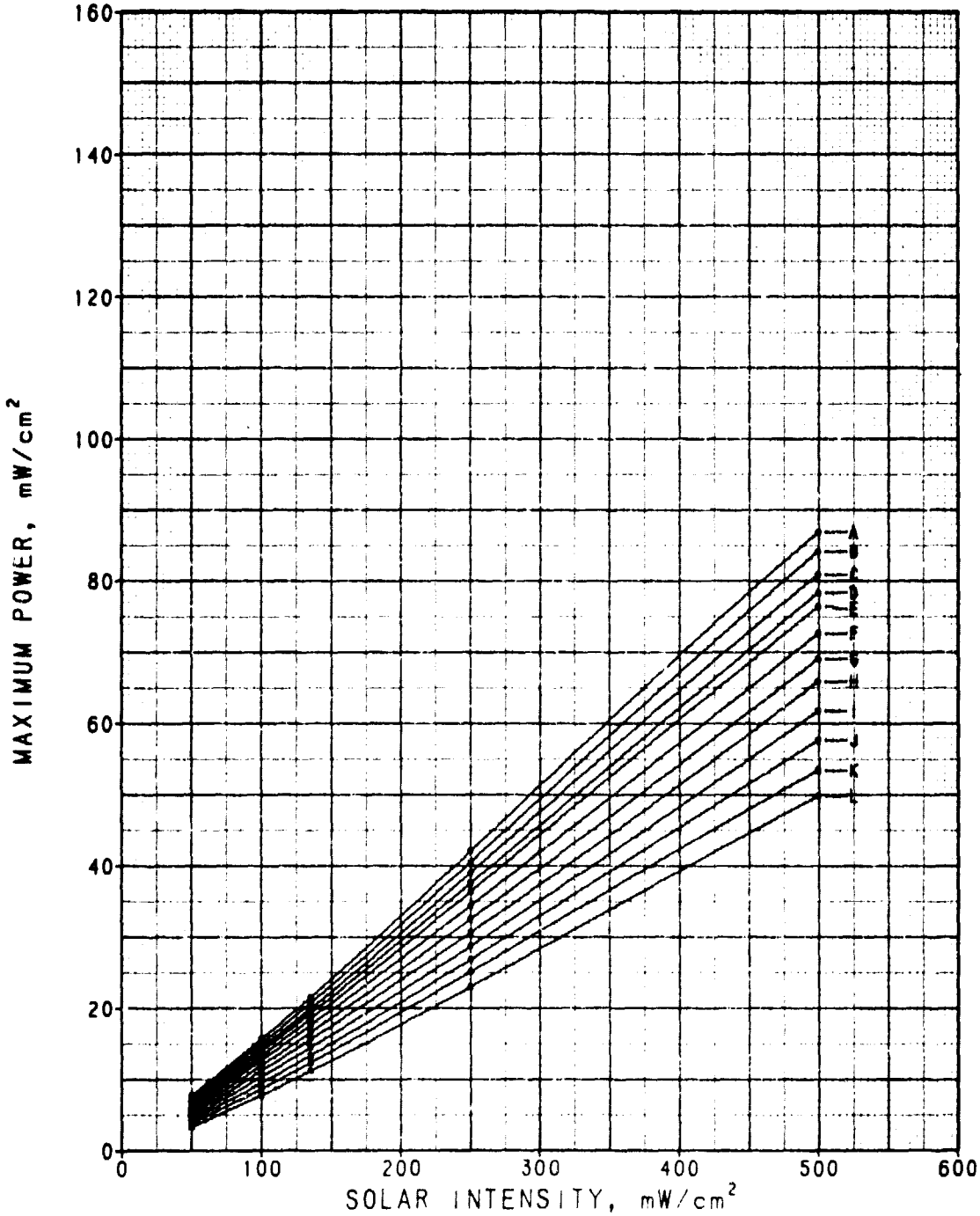
B	.0	J	160.0
C	20.0	K	180.0
D	40.0	L	200.0
E	60.0		
F	80.0		
G	100.0		
H	120.0		

HUGHES LPE GaAs CELLS (9/79)
P/N JUNCTION .LE. 0.5 MICRON
WINDOW .LE. 0.5 MICRON
2x2x.0305 cm (SAMPLE SIZE 7)
CONTACTS FRONT: (NI Ge Au)/Ag
REAR: Au-Zn/Ag
Ta_2O_5 AR COATING
7940 COVERSLIDE .03 cm TM-58

Figure 11. Average V_{mp} as a Function of Intensity



ID	°C	ID	°C
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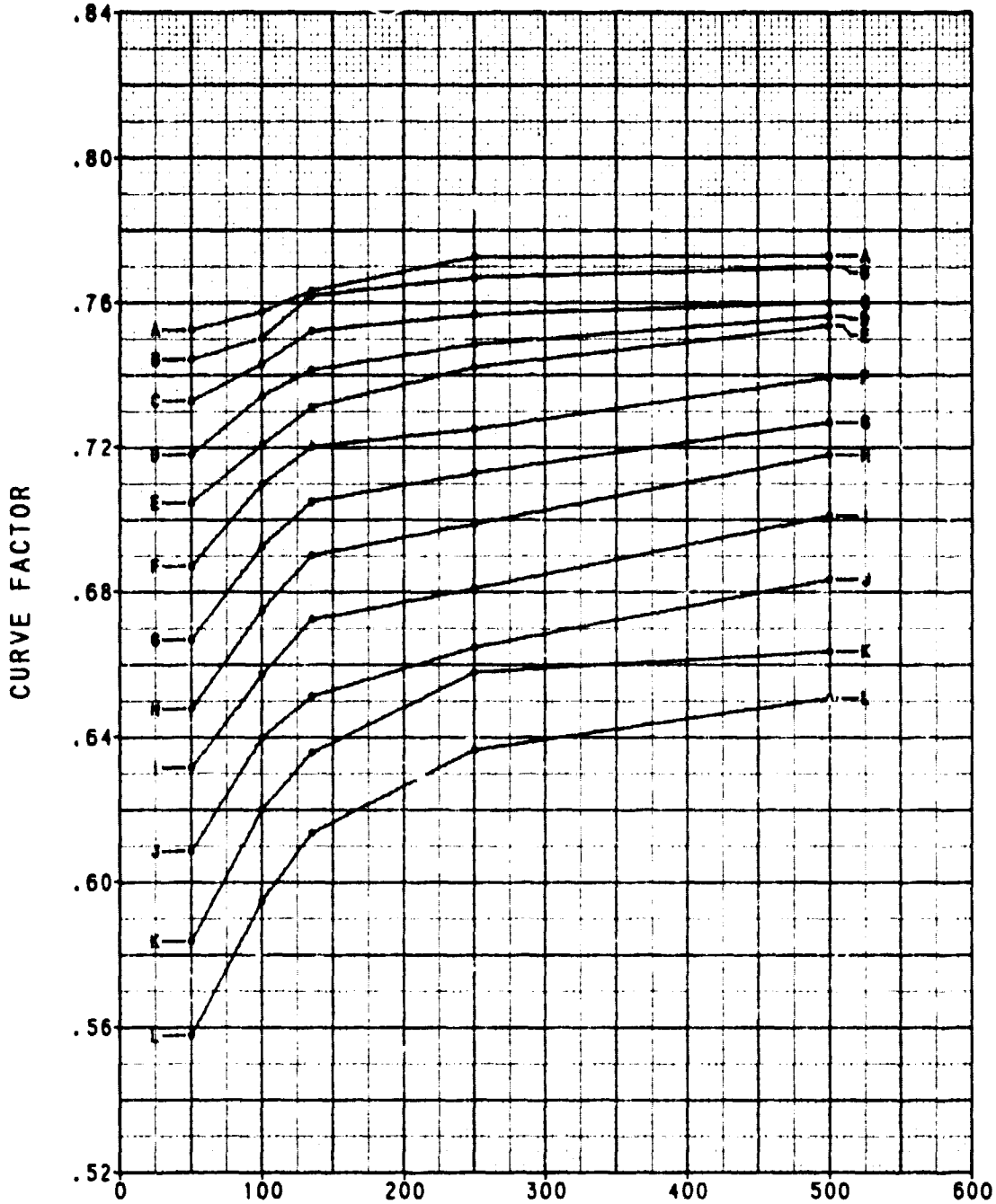
B	.0	J	160.0
C	20.0	K	180.0
D	40.0	L	200.0
E	60.0		
F	80.0		
G	100.0		
H	120.0		

HUGHES LPE GaAs CELLS (9/79)
P/N JUNCTION .LE. 0.5 MICRON
WINDOW .LE. 0.5 MICRON
2x2x.0305 cm (SAMPLE SIZE 7)
CONTACTS FRONT: (Ni Ge Au)/Ag
REAR: Au-Zn/Ag
Ta_2O_5 AR COATING
7940 COVERSLIDE .03 cm TM-58

Figure 12. Average P_{max}/cm^2 as a Function of Intensity



ID	°C	ID	°C
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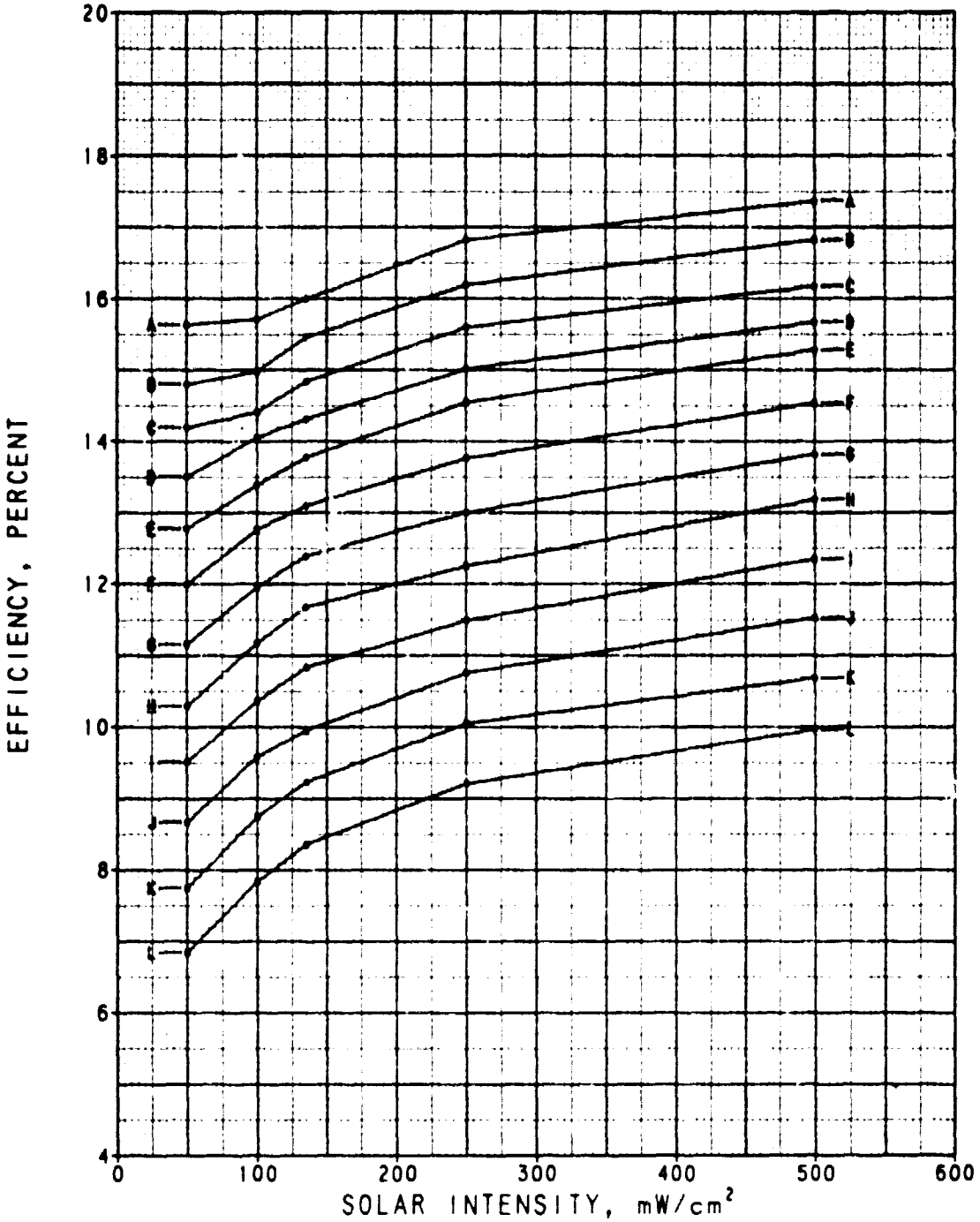
B	.0	J	160.0
C	20.0	K	180.0
D	40.0	L	200.0
E	60.0		
F	80.0		
G	100.0		
H	120.0		

HUGHES LPE GaAs CELLS (9/79)
P/N JUNCTION .LE. 0.5 MICRON
WINDOW .LE. 0.5 MICRON
2x2x.0305 cm (SAMPLE SIZE 7)
CONTACTS FRONT: (Ni Ge Au)/Ag
REAR: Au-Zn/Ag
Ta_2O_5 AR COATING
7940 COVERSLIDE .03 cm TM-58

Figure 13. Average Curve Factor as a Function of Intensity



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B	.0	J	160.0
C	20.0	K	180.0
D	40.0	L	200.0
E	60.0		
F	80.0		
G	100.0		
H	120.0		

HUGHES LPE GaAs CELLS (9/79)
P/N JUNCTION .LE. 0.5 MICRON
WINDOW .LE. 0.5 MICRON
2x2x.0305 cm (SAMPLE SIZE 7)
CONTACTS FRONT: (Ni Ge Au)/Ag
REAR: Au-Zn/Ag
Ta_2O_5 AR COATING
7940 COVERSLIDE .03 cm TM-5a

Figure 14. Average AMO Efficiency as a Function of Intensity

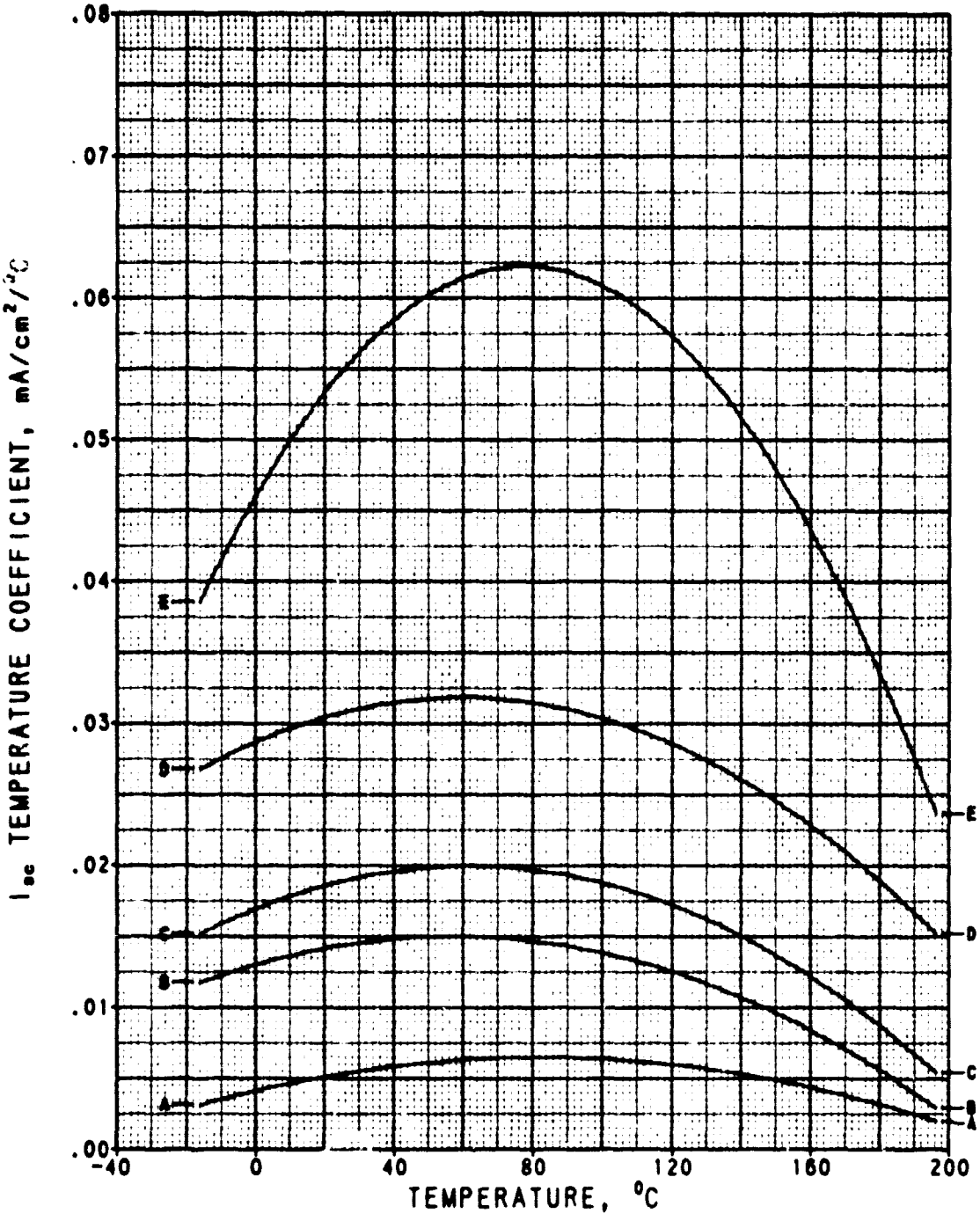
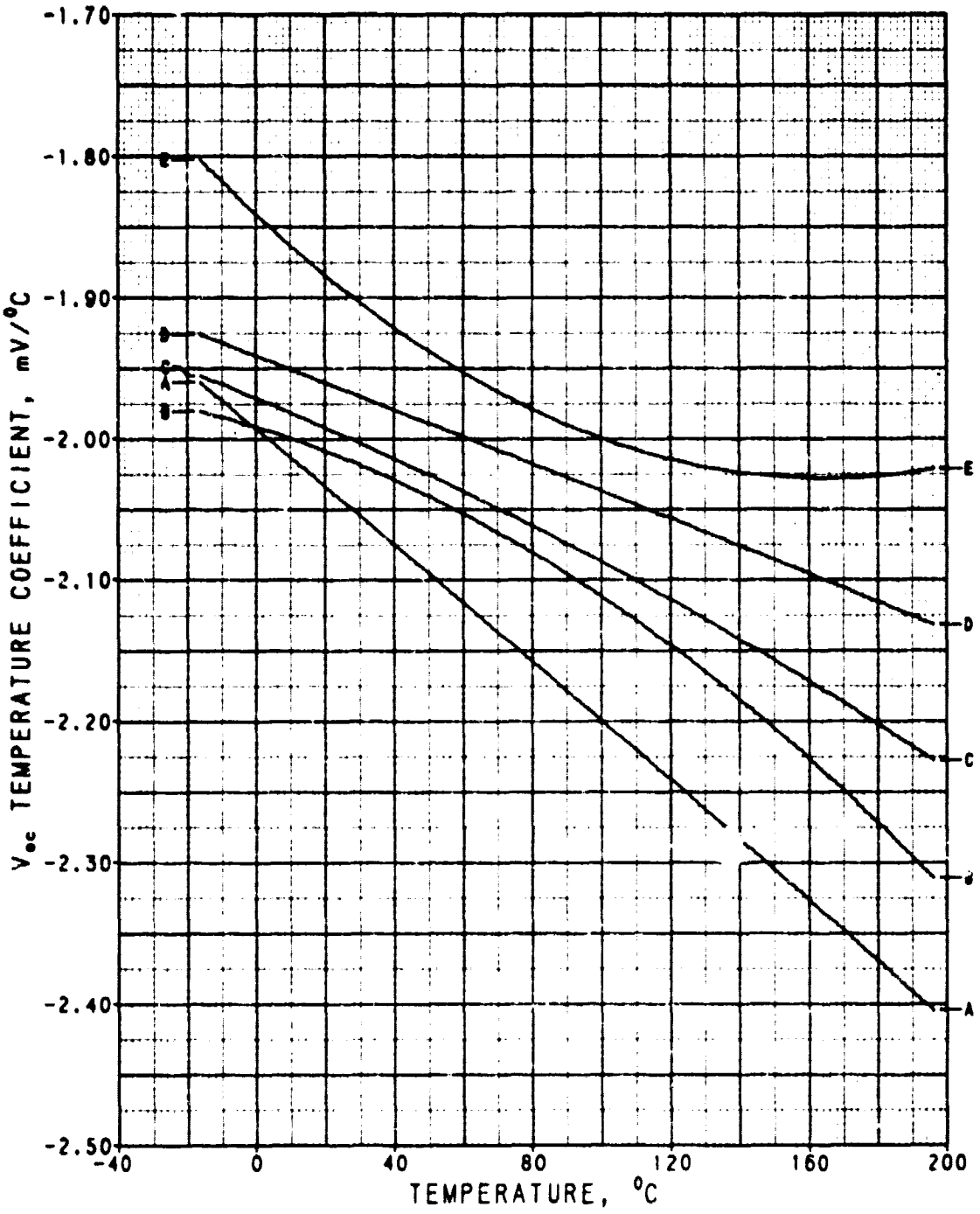


Figure 15. I_{sc} Temperature Coefficient



ID	mW/cm²
A	50.0
B	100.0
C	135.3
D	250.0
E	500.0

HUGHES LPE GaAs CELLS (9/79)
P/N JUNCTION .LE. 0.5 MICRON
WINDOW .LE. 0.5 MICRON
2x2x.0305 cm (SAMPLE SIZE 7)
CONTACTS FRONT: (NI Ge Au)/Ag
REAR: Au-Zn/Ag
Ta_2O_5 AR COATING
7940 COVERSLIDE .03 cm TM-58

Figure 16. V_{oc} Temperature Coefficient

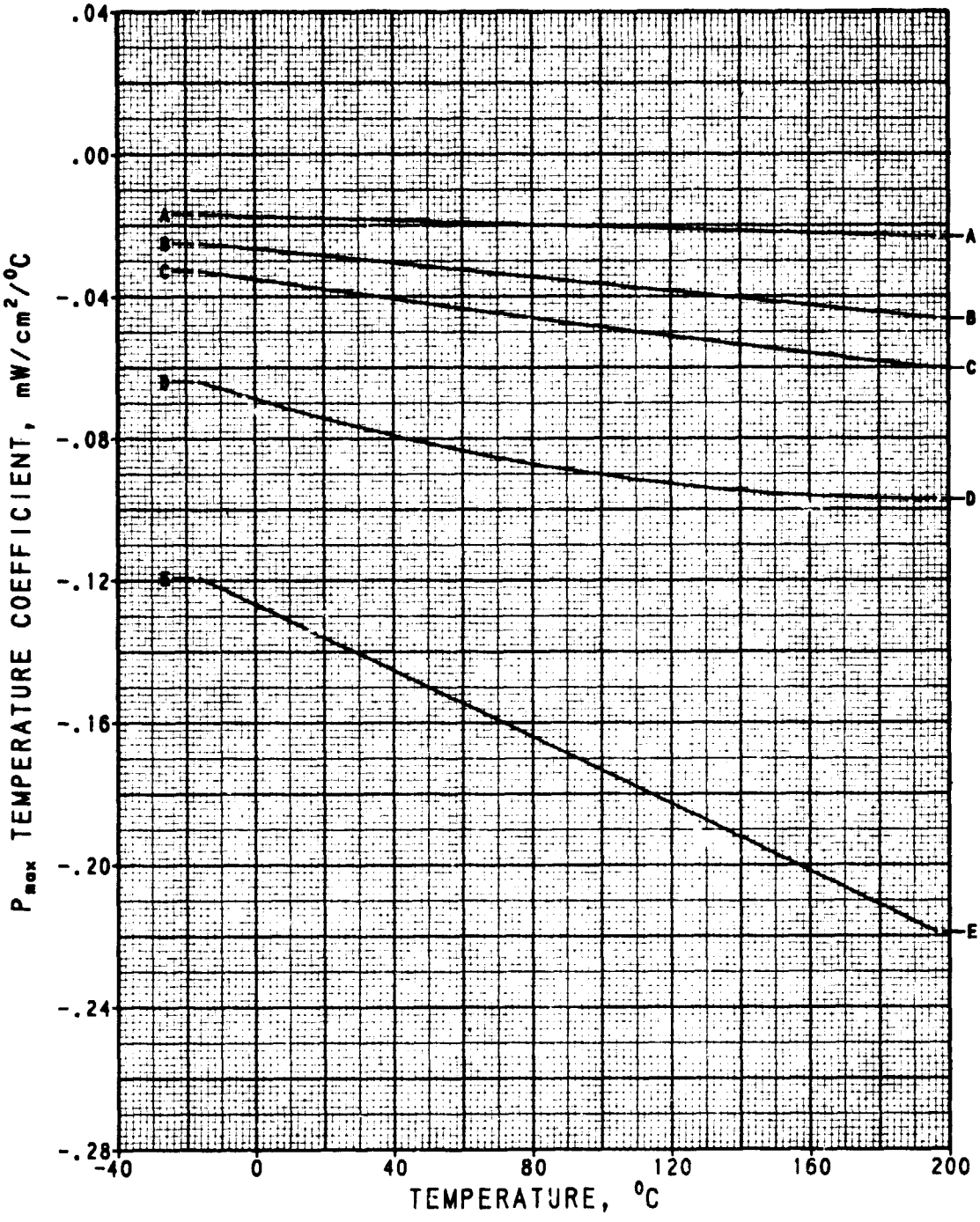
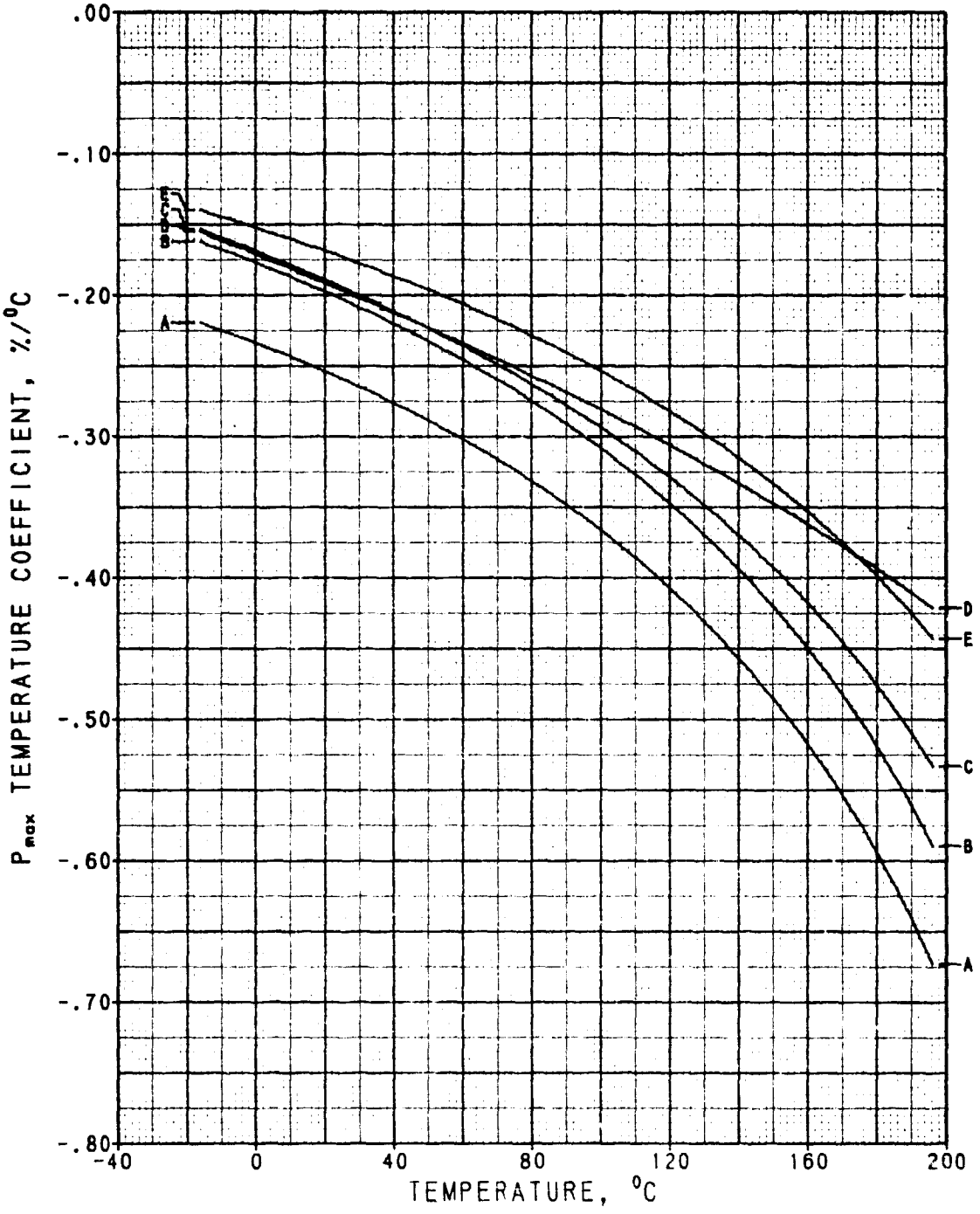


Figure 17. Absolute P_{max} Temperature Coefficient



ID	mW/cm²
A	50.0
B	100.0
C	135.3
D	250.0
E	500.0

HUGHES LPE GaAs CELLS (9/79)
P/N JUNCTION .LE. 0.5 MICRON
WINDOW .LE. 0.5 MICRON
2x2x.0305 cm (SAMPLE SIZE 7)
CONTACTS FRONT: (Ni Ge Au)/Ag
REAR: Au-Zn/Ag
Ta_2O_5 AR COATING
7940 COVERSLIDE .03 cm TM-58

Figure 18. Percent P_{max} Temperature Coefficient

Table 1. Average Short Circuit Current

HUGHES LPE GAAS CELLS (9/79)
P/N JUNCTION .LE. 0.5 MICRON
WINDOW .LE. 0.5 MICRON
2X2X.0305 CM (SAMPLE SIZE 7)
CONTACTS FRONT: (NI GE AU)/AG
REAR: AU-ZN/AG
TA2O5 AR COATING
7940 COVERSLIDE .03 CM TM-58

CELL TEMP. (DEG. C)	SOLAR INTENSITY (MW/CM**2) 50.00	100.00	135.30	250.00	500.00
-20.00	10.10	19.52	26.38	49.64	100.77
	(.17)	(.45)	(.55)	(1.10)	(2.09)
.00	10.06	19.51	26.51	49.84	101.15
	(.18)	(.45)	(.55)	(1.09)	(2.23)
20.00	10.21	19.73	26.80	50.53	102.03
	(.19)	(.45)	(.55)	(1.05)	(2.04)
40.00	10.36	20.29	27.32	51.18	103.27
	(.20)	(.47)	(.64)	(1.14)	(2.12)
60.00	10.47	20.60	27.85	52.08	104.97
	(.23)	(.47)	(.62)	(1.07)	(2.29)
80.00	10.60	20.89	28.15	52.75	106.10
	(.19)	(.46)	(.60)	(.96)	(2.16)
100.00	10.74	21.09	28.55	53.07	107.29
	(.18)	(.49)	(.57)	(1.07)	(2.32)
120.00	10.82	21.33	28.95	53.52	108.47
	(.20)	(.50)	(.61)	(1.02)	(2.51)
140.00	10.92	21.52	29.14	54.22	109.21
	(.21)	(.48)	(.60)	(1.17)	(2.22)
160.00	11.06	21.75	29.33	54.93	110.07
	(.22)	(.49)	(.59)	(1.10)	(2.30)
180.00	11.13	21.92	29.70	55.06	111.15
	(.24)	(.52)	(.62)	(1.13)	(2.81)
200.00	11.18	22.04	29.87	55.57	111.86
	(.22)	(.54)	(.68)	(1.07)	(2.69)

NOTE: STANDARD DEVIATIONS ARE GIVEN IN PARENTHESES.

Table 2. Average Open-Circuit Voltage

HUGHES LPE GAAS CELLS (9/79)
P/N JUNCTION .LE. 0.5 MICRON
WINDOW .LE. 0.5 MICRON
2X2X.0305 CM (SAMPLE SIZE 7)
CONTACTS FRONT: (NI GE AU)/AG
REAR: AU-ZN/AG
TA2O5 AR COATING
7940 COVERSLIDE .03 CM TM-58

CELL TEMP. (DEG. C)	SOLAR INTENSITY (MW/CM**2) 50.00	100.00	135.30	250.00	500.00
-20.00	1027.93	1062.00	1074.29	1096.23	1115.23
	(16.63)	(8.89)	(7.13)	(4.00)	(3.33)
.00	987.84	1022.54	1034.90	1058.80	1080.80
	(12.68)	(7.41)	(6.28)	(4.42)	(3.49)
20.00	948.37	982.24	995.23	1019.53	1043.07
	(10.30)	(6.52)	(5.78)	(3.88)	(2.76)
40.00	907.19	942.44	955.51	979.61	1002.97
	(8.86)	(6.44)	(5.16)	(3.61)	(5.68)
60.00	864.66	900.99	914.74	940.31	965.79
	(7.72)	(5.55)	(5.23)	(3.91)	(4.78)
80.00	822.53	859.76	873.61	899.07	926.53
	(7.06)	(5.09)	(4.91)	(4.35)	(4.14)
100.00	778.94	817.87	832.40	858.86	885.73
	(7.04)	(4.95)	(4.71)	(4.38)	(4.95)
120.00	733.90	775.51	790.50	818.11	846.37
	(7.08)	(5.32)	(5.21)	(4.76)	(4.91)
140.00	689.19	732.04	747.71	777.40	806.29
	(7.19)	(5.53)	(5.12)	(5.02)	(5.26)
160.00	643.27	688.17	704.26	735.93	765.84
	(7.21)	(5.67)	(5.71)	(5.11)	(4.51)
180.00	595.81	642.90	661.03	693.11	724.37
	(7.32)	(6.12)	(5.63)	(5.23)	(5.17)
200.00	548.26	597.07	616.49	650.36	684.33
	(7.75)	(6.25)	(6.11)	(5.79)	(5.23)

NOTE: STANDARD DEVIATIONS ARE GIVEN IN PARENTHESES.

Table 3. Average Maximum Power Current

HUGHES LPE GAAS CELLS (9/79)
P/N JUNCTION .LE. 0.5 MICRON
WINDOW .LE. 0.5 MICRON
2X2X.0305 CM (SAMPLE SIZE 7)
CONTACTS FRONT: (NI GE AU)/AG
REAR: AU-ZN/AG
TA?O5 AR COATING
7940 COVERSLIDE .03 CM TM-58

CELL TEMP. (DEG. C)	SOLAR INTENSITY (MW/CM**2) 50.00	100.00	135.30	250.00	500.00
-20.00	9.17	17.82	24.00	45.18	91.96
	(.23)	(.56)	(.60)	(.99)	(2.29)
.00	9.12	17.72	24.17	45.21	92.00
	(.24)	(.50)	(.57)	(1.24)	(2.21)
20.00	9.19	17.87	24.34	45.79	92.29
	(.24)	(.43)	(.67)	(1.01)	(1.85)
40.00	9.22	18.27	24.57	45.86	93.46
	(.21)	(.51)	(.73)	(1.18)	(1.69)
60.00	9.28	18.27	24.85	46.64	94.36
	(.26)	(.41)	(.69)	(.72)	(2.07)
80.00	9.27	18.49	24.98	46.57	94.43
	(.23)	(.51)	(.56)	(1.12)	(1.62)
100.00	9.28	18.40	25.01	46.46	94.89
	(.21)	(.49)	(.57)	(.78)	(1.74)
120.00	9.20	18.39	25.06	46.39	95.32
	(.15)	(.48)	(.54)	(.97)	(2.19)
140.00	9.18	18.23	24.98	46.32	94.75
	(.20)	(.47)	(.59)	(.90)	(2.26)
160.00	9.04	18.14	24.75	46.43	94.82
	(.20)	(.45)	(.61)	(.93)	(2.02)
180.00	8.86	17.86	24.49	46.46	94.50
	(.21)	(.48)	(.51)	(1.02)	(1.98)
200.00	8.67	17.50	24.22	46.04	94.11
	(.19)	(.56)	(.70)	(1.01)	(1.67)

NOTE: STANDARD DEVIATIONS ARE GIVEN IN PARENTHESES.

Table 4. Average Maximum Power Voltage

HUGHES LPE GAAS CELLS (9/79)
P/N JUNCTION .LE. 0.5 MICRON
WINDOW .LE. 0.5 MICRON
2X2X.0305 CM (SAMPLE SIZE 7)
CONTACTS FRONT: (NI GE AU)/AG
REAR: AU-ZN/AG
TA2O5 AR COATING
7940 COVERSLIDE .03 CM TM-58

CELL TEMP. (DEG. C)	SOLAR INTENSITY (MW/CM**2) 50.00	100.00	135.30	250.00	500.00
-20.00	851.86	881.29	901.29	930.86	944.71
	(21.56)	(20.32)	(17.83)	(12.50)	(16.52)
.00	811.14	845.00	865.29	895.43	914.86
	(16.81)	(13.82)	(14.48)	(13.20)	(14.70)
20.00	771.86	806.00	824.57	851.57	876.57
	(14.55)	(10.31)	(13.26)	(9.14)	(12.39)
40.00	731.57	768.71	788.29	818.57	838.29
	(9.16)	(12.97)	(9.59)	(8.70)	(9.16)
60.00	687.71	732.14	749.86	779.29	809.71
	(9.81)	(9.97)	(9.63)	(3.25)	(8.20)
80.00	646.43	689.57	709.14	738.43	769.71
	(9.73)	(10.03)	(9.97)	(7.79)	(8.20)
100.00	601.00	649.57	670.14	699.43	728.00
	(6.68)	(8.96)	(8.86)	(8.92)	(6.93)
120.00	558.71	607.43	630.29	659.71	691.43
	(11.37)	(8.02)	(9.71)	(4.72)	(5.62)
140.00	517.57	568.00	586.43	619.57	651.57
	(8.04)	(8.23)	(6.27)	(4.58)	(8.72)
160.00	479.14	528.00	543.71	578.86	607.57
	(8.30)	(6.73)	(8.42)	(7.49)	(9.03)
180.00	436.71	489.29	509.71	540.43	565.29
	(7.70)	(5.99)	(6.78)	(4.43)	(5.28)
200.00	394.29	447.14	466.43	499.71	529.29
	(6.80)	(7.71)	(5.03)	(6.26)	(4.03)

NOTE: STANDARD DEVIATIONS ARE GIVEN IN PARENTHESES.

Table 5. Average Maximum Power

HUGHES LPE GAAS CELLS (9/79)
P/N JUNCTION .LE. 0.5 MICRON
WINDOW .LE. 0.5 MICRON
2X2X.0305 CM (SAMPLE SIZE 7)
CONTACTS FRONT: (NI GE AU)/AG
REAR: AU-ZN/AG
TA2O5 AR COATING
7940 COVERSLIDE .03 CM TM-58

CELL TEMP. (DEG. C)	SOLAR INTENSITY (MW/CM**2) 50.00	100.00	135.30	250.00	500.00
-20.00	7.82	15.71	21.64	42.05	86.86
	(.32)	(.55)	(.73)	(.82)	(1.41)
.00	7.40	14.97	20.92	40.48	84.15
	(.27)	(.48)	(.60)	(1.02)	(1.82)
20.00	7.10	14.41	20.07	38.99	80.88
	(.24)	(.46)	(.58)	(.73)	(1.37)
40.00	6.75	14.04	19.36	37.53	78.35
	(.19)	(.45)	(.56)	(.78)	(1.63)
60.00	6.38	13.38	18.63	36.35	76.40
	(.20)	(.37)	(.54)	(.54)	(1.79)
80.00	5.99	12.75	17.71	34.38	72.68
	(.19)	(.35)	(.39)	(.65)	(1.20)
100.00	5.58	11.95	16.76	32.50	69.08
	(.15)	(.31)	(.36)	(.48)	(1.07)
120.00	5.14	11.17	15.79	30.61	65.90
	(.14)	(.31)	(.31)	(.64)	(1.31)
140.00	4.75	10.35	14.65	28.70	61.72
	(.14)	(.31)	(.33)	(.60)	(.95)
160.00	4.33	9.58	13.45	26.87	57.60
	(.15)	(.27)	(.39)	(.61)	(.73)
180.00	3.87	8.74	12.48	25.11	53.41
	(.12)	(.25)	(.30)	(.47)	(.79)
200.00	3.42	7.83	11.30	23.00	49.81
	(.12)	(.30)	(.32)	(.46)	(.83)

NOTE: STANDARD DEVIATIONS ARE GIVEN IN PARENTHESES.

Table 6. Average Curve Factor

HUGHES LPE GAAS CELLS (9/79)
P/N JUNCTION .LE. 0.5 MICRON
WINDOW .LE. 0.5 MICRON
2X2X.0305 CM (SAMPLE SIZE 7)
CONTACTS FRONT: (NI GE AU)/AG
REAR: AU-ZN/AG
TA2O5 AR COATING
7940 COVERSLIDE .03 CM TM-58

CELL TEMP. (DEG. C)	SOLAR INTENSITY (MW/CM**2) 50.00	100.00	135.30	250.00	500.00
-20.00	.7526	.7576	.7635	.7728	.7730
	(.0218)	(.0190)	(.0218)	(.0131)	(.0119)
.00	.7444	.7505	.7622	.7671	.7699
	(.0161)	(.0165)	(.0156)	(.0096)	(.0121)
20.00	.7330	.7432	.7524	.7568	.7601
	(.0150)	(.0139)	(.0147)	(.0066)	(.0110)
40.00	.7180	.7343	.7417	.7486	.7565
	(.0119)	(.0128)	(.0094)	(.0083)	(.0100)
60.00	.7047	7208	.7313	.7423	.7537
	(.0103)	(.0111)	(.0080)	(.0124)	(.0143)
80.00	.6871	.7100	.7203	.7251	.7395
	(.0102)	(.0100)	(.0076)	(.0077)	(.0107)
100.00	.6668	.6926	.7051	.7130	.7271
	(.0088)	(.0079)	(.0081)	(.0092)	(.0105)
120.00	.6477	.6750	.6903	.6990	.7180
	(.0091)	(.0071)	(.0075)	(.0096)	(.0127)
140.00	.6314	.6573	.6724	.6809	.7011
	(.0087)	(.0089)	(.0074)	(.0065)	(.0108)
160.00	.6085	.6399	.6513	.6648	.6835
	(.0087)	(.0077)	(.0102)	(.0107)	(.0120)
180.00	.5836	.6200	.6358	.6579	.6636
	(.0087)	(.0079)	(.0099)	(.0074)	(.0118)
200.00	.5577	.5948	.6136	.6365	.6508
	(.0097)	(.0120)	(.0091)	(.0059)	(.0116)

NOTE: STANDARD DEVIATIONS ARE GIVEN IN PARENTHESES.

Table 7. Average AMO Efficiency

HUGHES LPE GAAS CELLS (9/79)
P/N JUNCTION .LE. 0.5 MICRON
WINDOW .LE. 0.5 MICRON
2X2X.0305 CM (SAMPLE SIZE 7)
CONTACTS FRONT: (NI GE AU)/AG
REAR: AU-ZN/AG
TA2O5 AR COATING
7940 COVERSLIDE .03 CM TM-58

CELL TEMP. (DEG. C)	SOLAR INTENSITY (MW/CM**2) 50.00	100.00	135.30	250.00	500.00
-20.00	15.63	15.71	15.99	16.82	17.37
	(.64)	(.55)	(.54)	(.33)	(.28)
.00	14.80	14.97	15.46	16.19	16.83
	(.54)	(.48)	(.44)	(.41)	(.36)
20.00	14.19	14.41	14.83	15.59	16.18
	(.47)	(.46)	(.43)	(.29)	(.27)
40.00	13.50	14.04	14.31	15.01	15.67
	(.39)	(.45)	(.42)	(.31)	(.33)
60.00	12.77	13.38	13.77	14.54	15.28
	(.40)	(.37)	(.40)	(.21)	(.36)
80.00	11.99	12.75	13.09	13.75	14.54
	(.38)	(.35)	(.29)	(.26)	(.24)
100.00	11.15	11.95	12.39	13.00	13.82
	(.30)	(.31)	(.27)	(.19)	(.21)
120.00	10.28	11.17	11.67	12.24	13.18
	(.29)	(.31)	(.23)	(.26)	(.26)
140.00	9.51	10.35	10.83	11.48	12.34
	(.28)	(.31)	(.24)	(.24)	(.19)
160.00	8.66	9.58	9.94	10.75	11.52
	(.30)	(.27)	(.29)	(.24)	(.15)
180.00	7.74	8.74	9.23	10.04	10.68
	(.24)	(.25)	(.22)	(.19)	(.16)
200.00	6.84	7.83	8.35	9.20	9.96
	(.24)	(.30)	(.24)	(.18)	(.17)

NOTE: STANDARD DEVIATIONS ARE GIVEN IN PARENTHESES.

APPENDIX

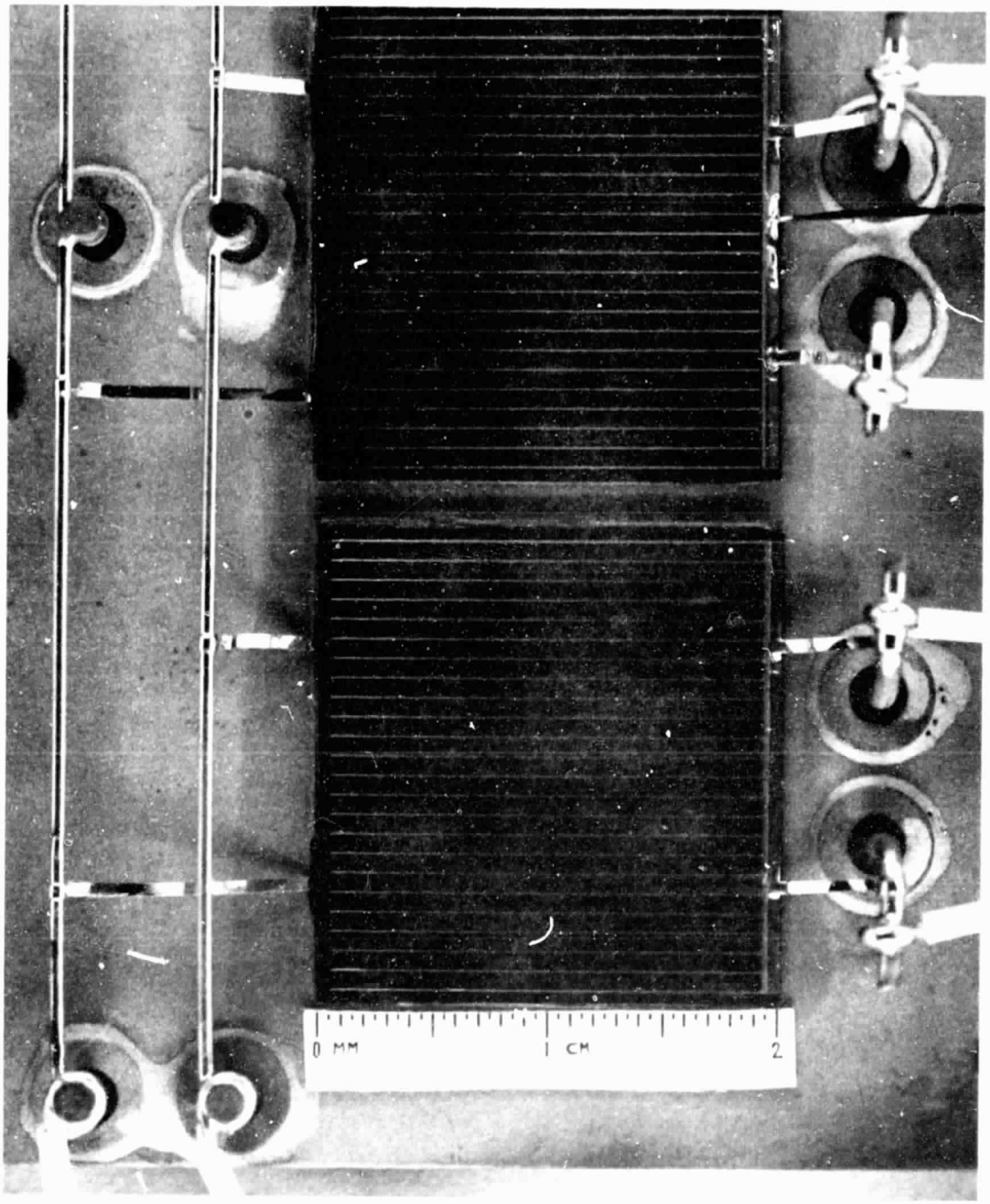


Figure A-1. Solar Cell

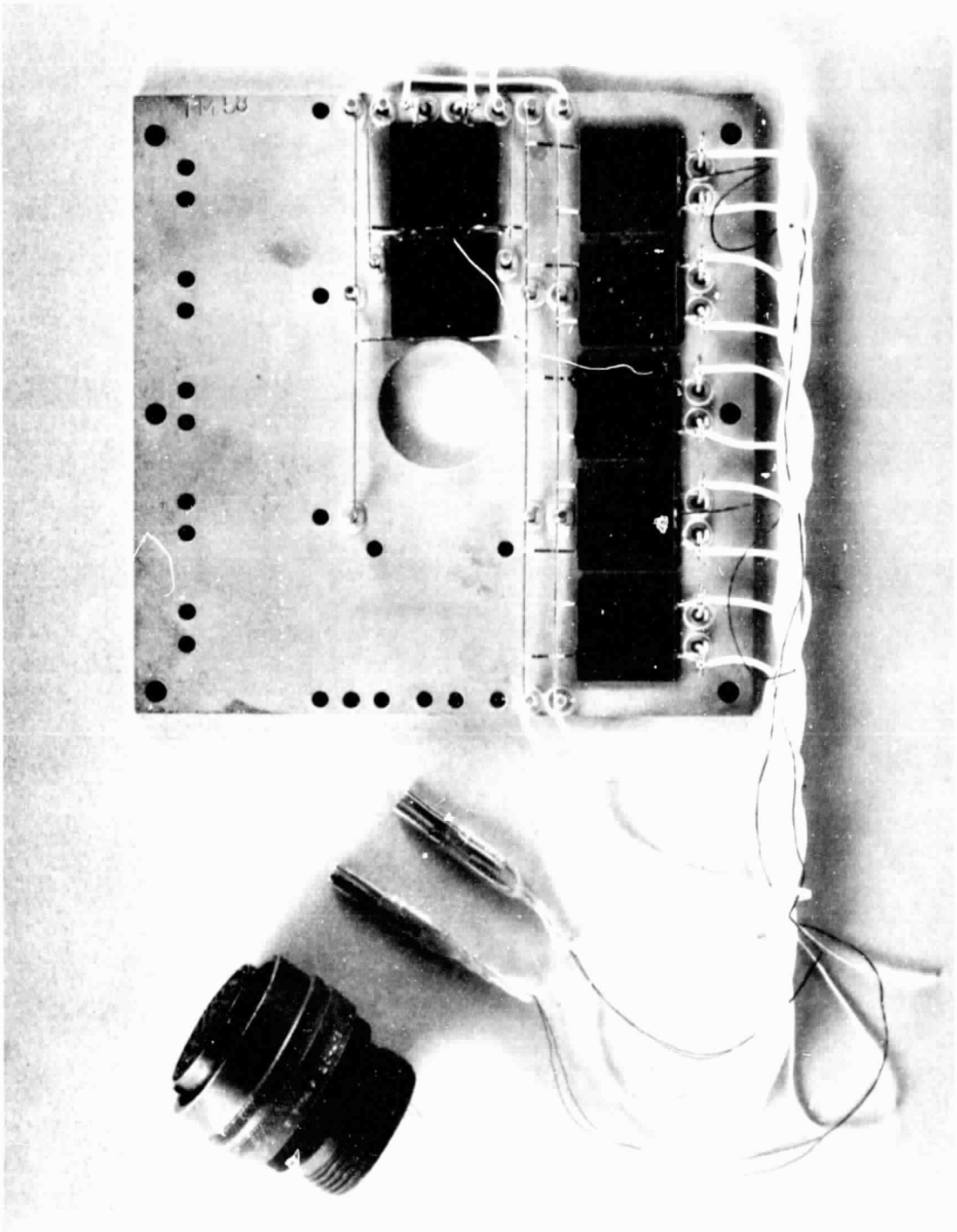


Figure A-2. Test Plate

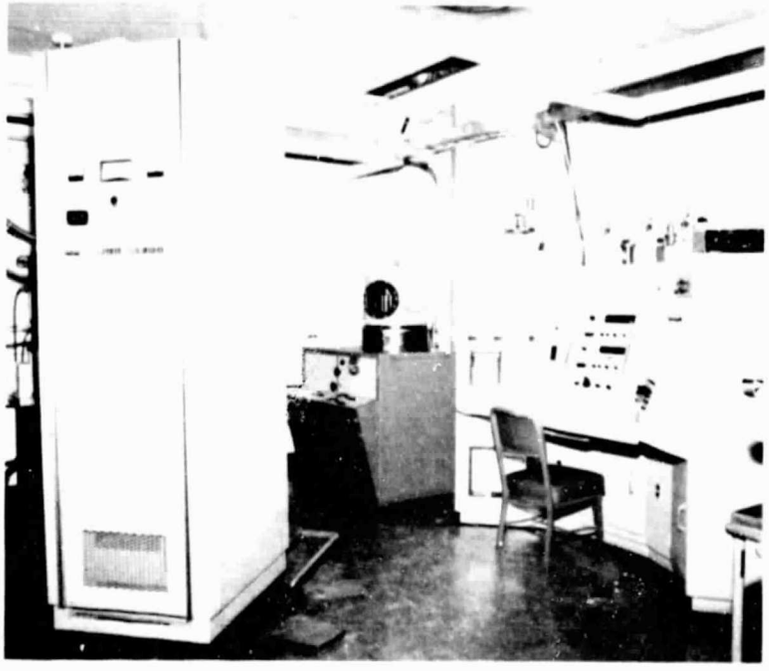


Figure A-3. Solar Cell Characterization Facility

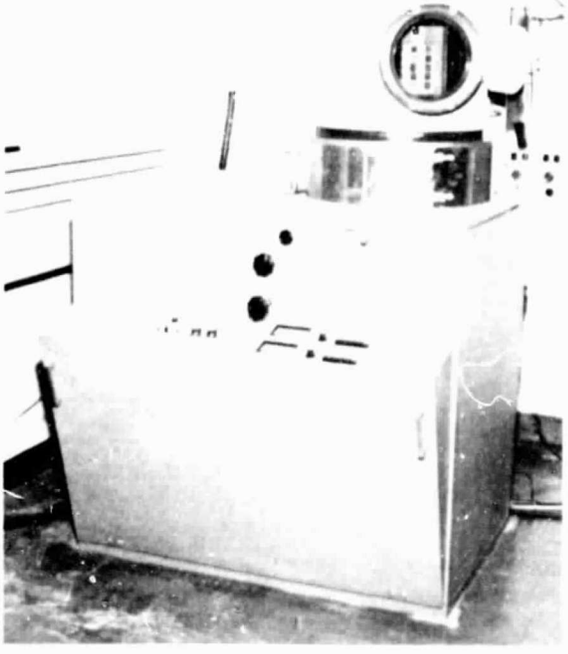


Figure A-4. Solar Cell Environmental Test Chamber